EOS Aura Science Team Meeting
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POSTERS

1. Comparison of MOPITT (Terra), AIRS (Aqua), and TES (Aura) CO total column products

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CO total column measurements (integrated vertical profiles) are provided by all three EOS spacecrafts since September, 2004. Thus, for a three-years-long period they can be compared for validation. The instruments have different designs: MOPITT is a gas-correlation spectrometer, AIRS is a grating spectrometer, TES is a high-resolution infrared-imaging Fourier transform interferometer. Our previous comparisons of MOPITT and AIRS with ground-based spectrometers revealed a good quality of the total column measurements for summer-time in mid-latitudes. Nevertheless, insufficient sensitivities of both instruments to the lower troposphere were found during night and winter time. The higher spectral resolution of TES promises even better results. Another point of interest is a comparison of three instruments during major biomass burning events, both in equatorial and boreal zones. These data correlate with aerosol index provided by OMI (Aura). Total column CO amounts integrated over vast areas supply information about gross emissions of carbon monoxide during fires and can be traced further for estimates of emissions of total carbon and perturbations to the global carbon cycle.

2. Exploration of Stratopause and Tropopause Evolution in Polar Winter in Satellite Data and Meteorological Analyses

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Until the past several years, daily global or hemispheric temperature datasets extending through the mesosphere were largely unavailable. With the launch of the Sounding of the Atmosphere with Broadband Emission Radiometry (SABER) instrument in 2002 and the Aura Microwave Limb Sounder (MLS) in 2004, we now have a wealth of such data. In addition, the Atmospheric Chemistry Experiment-Fourier Transform Spectrometer (ACE-FTS) has been recording daily temperature profiles at high latitudes in the polar winter of both hemispheres since 2004. Some data centers, particularly the European Center for Medium-Range Weather Forecasting (ECMWF) and NASA's Global Modeling and Assimilation Office (GMAO) are now providing assimilated meteorological analyses at levels into the mesosphere; however, above the upper stratosphere, there are no direct data constraints, so the fields depend strongly on the dynamics and parameterizations in the underlying general circulation models, and there have heretofore been few data with which to compare them. We use MLS, SABER, ACE-FTS, as well as ground-based data, to detail the evolution of the stratopause during recent polar winters, and to assess the skill of the analyses in capturing the observed behavior. The stratopause evolution is also viewed in the context of the underlying tropopause evolution and the phenomena that

connect them. We show examples of stratopause/tropopause evolution during stratospheric sudden warmings, and examine interannual and interhemispheric variability.

3. Three Summers of Ozone Profiles over Beltsville, MD: A Study of Free-Tropospheric and Boundary Layer Ozone

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A total of 51 ozonesonde launches were made in Beltsville, MD during the summers of 2004 through 2006 as part of 3 different field campaigns; INTEX Ozonesonde Network Study 2004 (IONS-04, http://croc.gsfc.nasa.gov/intex/ions.html), Howard/NCAS ozonesondes for MDE (Maryland Department of the Environment) Pollution Episodes (http://www.physics1.howard.edu), and the Water Vapor Validation Experiment – Satellite/Sondes 2006 (WAVES, http://ecotronics.com/lidar-misc/WAVES.htm). These profiles were used to characterize variability in sources of free-tropospheric ozone. On average, free-tropospheric ozone was composed of the following: 10% regional convection and lightning-derived NO, 25% stratospheric ozone, with the balance (~65%) a mixture of aged air of indeterminate origin and recently advected ozone. A separate analysis of local emission and boundary layer ozone was performed. The data from 2005 and 2006 includes both nighttime and daytime launches, permitting an investigation between planetary boundary layer processes and tropospheric ozone. In nighttime profiles with above average column ozone in the residual layer, daily maximum 1 hr and 8 hr average surface ozone values were roughly 10 ppbv greater than days with below average column ozone in the residual layer. These results were also compared to the NOAA/EPA Operational Air Quality Model 1 hr and 8 hr average surface ozone forecasts for Beltsville.

4. Intercomparison of Ground-based Column Ozone Measurements with Aura Satellite Retrievals over Richland, WA

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The Pennsylvania State University Department of Meteorology Nittany Atmospheric Trailer and Integrated Validation Experiment (NATIVE) is a mobile atmospheric research facility that was deployed in Richland, WA from April 21, 2006 through May 15, 2006 as part of the INTEX-B (Intercontinental Chemical Transport Experiment) campaign. During this period, NATIVE made column and vertical profile ozone measurements using ozonesondes, a Microtops Sunphotometer, and a UV-MFR (Ultraviolet Multifilter Radiometer). These measurements were compared with Aura Ozone Monitoring Instrument (OMI) total column ozone (TCO) derived using the DOAS and TOMS 8 retrieval algorithms and the tropospheric ozone residual (TOR) derived by subtracting the stratospheric column ozone (SCO) from the TCO. Sonde-measured TCO is on average 13 DU higher than OMI-derived TCO. Microwave Limb Sounder (MLS) SCO is generally lower than the sonde-derived SCO. Back-trajectories and EPV maps were used to identify possible tropopause fold events, which may create large horizontal gradients in ozone and cause discrepancies among the measurements. Finally, sensitivities of each instrument to various parameters such as presence of ozone-rich

layers and cloud cover were identified. In general, the DOAS technique gives higher TCO than TOMS 8 but the opposite is true when cloud cover exceeds 0.2.

5. Comparison of MLS Ozone and Ozonesonde Profiles over Hilo, Hawaii.

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MLS ozone profiles have been compared with ozonesondes launched at Hilo, Hawaii by the NOAA/Mauna Loa Observatory. The MLS data used were 105 version 1.5 overpasses, and 46 version 2.2 overpasses between August, 2004 and December, 2006. The MLS and ozonesondes overlapped between 14.678 and 215 hPa. The tropopause above Hilo is typically between 16 and 17.5 km (110 to 84 hPa) and the air masses range from pure tropical to mid-latitude depending on transport conditions. On average at nearly all pressures in the overlap region for both MLS versions, the ozonesonde measured lower values of ozone. In the stratosphere, where the mixing ratio was above 1 ppm, the relative difference ranged from -1 to -10%. In the troposphere, where the mixing ratio is much smaller, the relative difference was much larger especially at 215 hPa. Version 2.2 data generally showed improvement in the agreement with the sonde .

6. Comparisons of MIPAS and HIRDLS/OMI/TES Cloud Products

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Clouds are a source of major uncertainty in climate models - it is thus important to accurately model clouds in order to both detect their presence in satellite measurements and to determine their properties. In this work, a macrophysical cloud parameter retrieval using the Michelson Interferometer for Passive Atmospheric Sounding MIPAS (an infrared limb-sounding Fourier Transform spectrometer onboard ESA-ENVISAT, launched in 2002) is compared against cloud products from HIRDLS, OMI and TES instruments onboard NASA's AURA satellite. Three macrophysical cloud parameters (cloud top height, cloud top temperature and cloud extinction coefficient) are retrieved from MIPAS spectra as they represent the most obvious physical, thermodynamic and optical properties, respectively, of a cloud. These quantities will be compared with HIRDLS/OMI/TES cloud top height/pressure, inferred HIRDLS/TES cloud top temperature and TES optical depth, respectively. As well, there will be a brief analysis of cloud frequency as detected by the different instruments considered. Comparisons will be carried out both for individual coincident cases and statistically over the globe for May 2006.

7. Trends and variability of mid latitude stratospheric water vapor deduced from the re-evaluated Boulder balloon series and HALOE

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An updated trend analysis of water vapor in the lower mid latitude stratosphere from the Boulder balloon-borne NOAA frostpoint hygrometer measurements and from the Halogen Occultation Experiment (HALOE) is presented. Two corrections for

instrumental bias are applied to homogenize the frostpoint data series, and a quality assessment of all soundings after 1991 is presented. Linear trend estimates based on the corrected data for the period 1980-2000 are up to 40% lower than previously reported. Vertically resolved trends and variability are calculated with a multi-regression analysis including the quasi-biennal oscillation and equivalent latitude as explanatory variables. In the range of 380 to 640 K potential temperature (~14 to 25 km), the frostpoint data from 1981 to 2006 show positive linear trends between 0.3±0.3 and 0.7±0.1%/yr. The same dataset shows trends between -0.2±0.3 and 1.0 ±0.3 %/yr for the period 1992 to 2005. HALOE data over the same time period suggest negative trends ranging from -1.1±0.2 to -0.1±0.1 %/yr. In the lower stratosphere, a rapid drop of water vapor is observed in 2000/2001 with little change since. At higher altitudes, the transition is more gradual, with slowly decreasing concentrations between 2001 and 2007. This pattern is consistent with a change induced by a drop of water concentrations at entry into the stratosphere. Previously noted differences in trends and variability between frostpoint and HALOE remain for the homogenized data. Due to uncertainties in reanalysis temperatures and stratospheric transport combined with uncertainties in observations, no quantitative inference about changes of water entering the stratosphere in the tropics could be made with the mid latitude measurements analyzed here.

8. Global Observations of HNO3 from the High Resolution Dynamics Limb Sounder (HIRDLS) – First results

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We show the first evaluation of the HNO3 data product (version 2.02.07) from the High Resolution Dynamics Limb Sounder (HIRDLS) on the Earth Observing System (EOS) Aura satellite. The HIRDLS instrument obtains approximately 5400 HNO3 profiles per day. HIRDLS HNO3 data are generally good over the latitude range of 64ºS to 80ºN and pressure range 100 hPa to 10 hPa, with some profiles, depending on latitude, having useful information between 100 hPa to 161 hPa and 10 hPa to 1.9 hPa. The individual profile precisions are between 10-30%, under optimal conditions, but can be much larger if the HNO3 abundance is low or outside the 100 hPa to 10 hPa region. Global results are compared with the HNO3 observations from version 2.2 of the EOS Aura Microwave Limb Sounder (MLS) and many large scale features are consistent between the two instruments. HIRDLS HNO3 is compared with 225 Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) and coincident profiles. In these comparisons, the HIRDLS HNO3 data are biased low by 10-50% depending on altitude. The HIRDLS HNO3 is also compared to in situ data taken by the NOAA Chemical Ionization Mass Spectrometer (CIMS) instrument flown during the 2005 NASA Houston Aura Validation Experiment (AVE). The comparison of HIRDLS HNO3 to NOAA CIMS in the mid-latitudes, lowermost stratosphere, is in good agreement. This result is very encouraging and suggests that the HIRDLS HNO3 data in the lower stratosphere will be useful for scientific investigations.

9. A study of tropospheric ozone column enhancements over North America using a regional model and satellite data

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We examine the variability of tropospheric ozone columns (TCOs) using a 3-D Regional chEmical trAnsport Model (REAM), the Aura derived tropospheric ozone residuals (TORs) and the Tropospheric Emission Spectrometer (TES) measurements for spring and summer 2005. PV/Geopotential height mapping and 2-D interpolation techniques have been applied to Microwave Limb Sounder (MLS) profiles to derive the Ozone Monitoring Instrument (OMI)/MLS tropospheric ozone columns. Comparisons of monthly mean distributions show good agreement between OMI/MLS tropospheric ozone columns, REAM columns, and TES columns. Two six-day periods in March have been selected to study the periodic TCO enhancements in two regions, around the Baja peninsula (Mexico) and on the west coast of California. Several processes are indicated to have influenced the high TCO values. Thirteen day back trajectories and daily maps of carbon monoxide (CO) and ozone from GEOS-CHEM and OMI/MLS have been integrated to investigate the influence of cross-Pacific transport. The high ozone concentration in the mid- and lower- troposphere over the west coast of California is concluded to have been influenced by cross-Pacific transport. Meteorological fields indicate that the high ozone concentrations in the upper troposphere over the west coast of California and the high TCOs over the Baja peninsula were associated with a stratospheric intrusion through a deep Rossby wave breaking event. The correlation between REAM TCOs and the surface ozone from Environmental Protection Agency ground network measurements suggest that the TCO enhancement over the west coast is also associated with an increase of surface ozone. The correlations with geopotential height, wind fields, and tropopause height suggest that TCO enhancement is best characterized in spring time by geopotential height decreases on the 500 mb surface.

10. Seasonal variations in upper stratospheric MLS HOCl, and model comparisons

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We review the status of the MLS HOCl retrievals, and estimates of the MLS precision and accuracy for this product. Averages such as weekly or monthly zonal means are needed for HOCl because of the weak MLS HOCl radiance signal. MLS HOCl is only recommended for use in the upper stratosphere, from about 10 to 2 hPa, given known retrieval artifacts for pressures larger than 10 hPa. We focus here on observed relative changes, such as seasonal variations since the Aura launch, using both MLS version 2.2 and 1.5 data. Comparisons versus expected seasonal variations are provided, using model runs from both SLIMCAT and WACCM3. This kind of study should provide a broader global view and understanding of this difficult to measure stratospheric constituent.

11. Characterizing Megacity Pollution with TES O3 and CO Measurements and Constraining Air Pollutant Emissions

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Concurrent tropospheric O3 and CO vertical profiles from the Tropospheric Emission Spectrometer (TES) during the MILAGRO/INTEX-B aircraft campaigns over the Mexico City Metropolitan Area (MCMA) allow us to characterize mega-city pollution. Outflow from the MCMA occurred predominantly at 600-800 hPa, evident in O3, CO, and NOx enhancements in the in situ observations. We examined O3, CO, and their correlation at 600-800 hPa from TES retrievals, aircraft measurements, and GEOS-Chem model results over the aircraft coverage (within a radius of ~700 km around the MCMA). The enhancements in O3 and CO seen in the in situ measurements are not apparent in TES data, due to the lack of TES coverage during several strong pollution events. However, TES O3 and CO data are consistent with the aircraft observations on a daily mean basis (50 – 60 and 100 – 130 ppbv for background O3 and CO, respectively). The O3-CO correlation coefficients and enhancement ratios (dO3/ dCO) derived from TES data are in good agreements with those derived from the aircraft observations and GEOS-Chem model results (r: 0.5-0.9; dO3/ dCO: 0.3-0.4), reflecting significant springtime photochemical production over the MCMA and the surrounding region. In an ongoing study, we further explore the use of satellite observations to constrain the global emissions of EPA criteria air pollutants/ozone precursors NOx, CO and isoprene. The GEOS-Chem model and its adjoint are applied for global inversions of SCIAMACHY NO2 and CH2O columns and TES ozone and CO data. We present here some preliminary results from a global adjoint inversion of SCIAMACHY tropospheric NO2 column data to constrain NOx emissions.

12. Effect of Convection on the Tropical Tropopause Layer over the Tropical Americas

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Water vapor and ozone are the most important gases that regulate the radiative balance of the Tropical Tropopause Layer (TTL). Their radiative contribution dictates the height within the TTL and the rate at which air either ascends into the tropical stratosphere or subsides back to the tropical troposphere. The details of the mechanisms that control their concentration, however, are poorly understood. One of such mechanisms is convection that reaches into the TTL. In this study, we will present evidence from space-borne observations of the impact that convection has on water vapor, ozone, and temperature in the TTL over the Tropical Americas where deep and overshooting convection have the highest frequency of occurrence in the tropics. We explore the effect of convective systems such as hurricanes during the 2005 season using the Microwave Limb Sounder (MLS) on Aura version 1.5 data and more recent tropical systems using the newly released version 2 data with higher vertical resolution. In order to provide the horizontal extent and the vertical structure of the convective systems, we use data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua, the Microwave Humidity Sensor (MHS) on NOAA-18, and CloudSat when available.

13. Using horizontal transport characteristics to infer the emission altitude of a volcanic SO2 plume

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OMI measurements in the vicinity of the Nyamuragira volcano (1.4S, 29.2E) showed large amounts of SO2 emitted during late November/early December, 2006. A series of forward and backward trajectories together with OMI and AIRS SO2 measurements are used to determine the injection altitude from the horizontal transport characteristics of the SO2 plume. Different statistical methods are used, including PDFs of the distance of closest approach and Lagrangian autocorrelation functions conditioned on the assumed altitude of the plume. Sensitivity to the meteorological data is also investigated. The inferred altitude of the SO2 cloud is verified by comparing with the altitude of aerosols emitted by the volcano using the aerosol backscatter vertical profiles from CALIPSO where available.

14. MIPAS comparisons with HIRLDS V2.04.08 radiances and L2 products

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The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is Fourier Transform spectrometer which measures in the infrared from 685 to 2410 wavenumbers. MIPAS is a limb viewing instrument on ESA's ENVISAT satellite which was launched in March 2002. Since August 2004 MIPAS has been operating at a reduced spectral resolution of 0.0625 cm-1. For selected test day the HIRDLS v2.04.08 radiances have been directly compared to those measured by MIPAS for the ten HIRDLS channels which are completely covered by the MIPAS spectral bands. A local optimal estimation retrieval code (the MIPAS Orbital Retrieval using Sequential Estimation (MORSE)) has been used to retrieve volume mixing ratio (VMR) profiles for all HIRDLS species from the ESA level 1B reduced resolution MIPAS data. These profiles have been compared to HIRDLS v2.04.08 level 2 retrievals. A simulated MIPAS radiance spectrum which covered the full HIRDLS spectral range was created by using the MIPAS retrieved profiles as the input for a forward model (the Oxford Reference Forward Model (RFM)). This simulated MIPAS spectrum allowed MIPAS radiances to be indirectly compared to HIRDLS v2.04.08 radiance for channels which direct comparisons are not possible.

15. Ozonesonde observations during the Sodankylä Total Ozone Intercomparison and Validation Campaign (SAUNA)

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The Sodankylä Total Ozone Intercomparison and Validation Campaign (SAUNA) in March -April 2006 in Sodankylä, Finland (67.4 ºN, 26.6 ºE) was one the major field campaigns to validate the performance of ground-based and satellite borne ozone sensors at high latitudes. Among other measurements a total of 33 balloon borne ozonesonde observations were made in the time period of March 22- April 14, 2006 timed to the ozone measurements on board the NASA Aura satellite. The sounding system used was the new version of the DigiCora ground station and the Metgraph software by Vaisala

allowing to use the digital RS92-SGP radiosondes. The ozonesondes reached the average altitude of 7 hPa, which allows reliable total column estimation. In this paper total ozone from sondes is compared to the total ozone measurements based on five Brewer spectrophotometers operated in Sodankylä during the campaign and the OMI instrument on board the Aura satellite. In addition, profile comparison with ozone LIDAR and space born profiling instruments is provided, and results from dual ozonesonde flights. In each dual sonde payload an EN-SCI ozonesonde was flown using 0.5 % KI sensing solution and a SPC ozonesonde using 1% KI solution.

16. Quantifying the trans-Pacific transport of Asian pollution in the upper troposphere with Aura-MLS observations

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Trans-Pacific transport of Asian pollution has received considerable attention because of its global air quality and climate implications. It has been difficult to investigate long-range transport of pollution in the upper troposphere because of the lack of suitable observations. The launch of Aura-EOS, with its measurements of upper tropospheric carbon monoxide (CO) and ozone among other species, makes it possible for the first time to systematically examine long-range transport in the upper troposphere. In this study we present an analysis of Aura-MLS upper tropospheric observations of CO and ozone, in conjunction with a global 3-D chemical transport model (GEOS-CHEM), with a focus on (1) quantifying the temporal variability (i.e., frequency and strength) of trans-Pacific transport of Asian pollution in the upper troposphere, (2) delineating transport events in the upper troposphere from the ones in the middle and lower troposphere by combining and contrasting MLS and MOPITT observations of CO, and (3) examining the preferred meteorological conditions and associated processes including warm conveyor belt (WCB) that are responsible for these upper troposphere trans-Pacific transport of pollution.

17. Investigation of sources of upper tropospheric biases in TES retrievals

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Results of validation studies for the Tropospheric Emission Spectrometer (TES) indicate that biases are present in the retrieved temperature, water vapor and ozone in the upper troposphere. Possible sources of the observed biases include errors in the spectroscopic parameters used in the forward model as well as issues with the modeling and retrieval of clouds and surface emissivity. The impact of these errors on forward modeled radiances and retrieved profiles is examined here using selected cases. The results of this investigation will not only lead to improvements in future TES retrieval processor versions, but will also have relevance for other infrared sounders such as AIRS and IASI.

18. Intra-seasonal variability in tropospheric ozone and water vapor in the tropics

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Nearly two years of tropospheric O3 and H2O data from the Ozone Monitoring Instrument (OMI) and Microwave Limb Sounder (MLS) instruments on the Aura satellite are analyzed to study the zonal characteristics of intra-seasonal oscillation (ISO) of 20-100 day periods. The analysis shows the presence of ISO signals in O3 and H2O throughout much of the tropics including the north Atlantic not shown in previous studies. ISO variability west of the dateline appears as a manifestation of eastward propagation of the Madden-Julian Oscillation (MJO). Time series of tropospheric O3 and H2O are negatively correlated throughout much of the tropics, and mostly over ocean. This suggests lofting of air from convection as a basic driving mechanism, with convection transporting low amounts of O3 and high amounts of H2O upwards from the boundary layer. ISO/MJO related changes in O3 and H2O are a major source of variability and often exceed 25% of background concentrations.

19. Pseudo-Lagrangian Observations of the Long-Range Transport of Pollution Using the TES Instrument

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The Tropospheric Emission Spectrometer (TES) is an infrared instrument which was launched onboard NASA's Aura satellite in 2004. TES is the first instrument to provide vertical information on tropospheric ozone whilst simultaneously measuring CO on a global basis. In support of the Intercontinental Chemical Transport Experiment-B (INTEX-B) campaign, which took place in March-May 2006, TES made extensive measurements over the north Pacific region, extending from the East Asian coast across to the Western seaboard of the United States. This enabled TES to observe trans-pacific transport events of pollution from Asia across the pacific towards the United States, which may also have been intercepted by INTEX-B aircraft. Here we present a case study which demonstrates the ability of the TES instrument to observe the long-range transport of pollution.

20. A study of stratospheric chlorine partitioning based on new satellite measurements and modeling

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Two recent satellite instruments --- the Microwave Limb Sounder (MLS) on Aura and the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) on SCISAT-1 --- provide an unparalleled opportunity to investigate stratospheric chlorine partitioning. We use measurements of ClO, HCl, ClONO2, and other species from MLS and ACE-FTS to study the evolution of reactive and reservoir chlorine throughout the lower stratosphere during two Arctic and two Antarctic winters characterizing both relatively cold and relatively warm and disturbed conditions in each hemisphere. At

middle latitudes, and at high latitudes at the beginning of winter, HCl greatly exceeds ClONO2, representing ~0.7--0.8 of estimated total inorganic chlorine. Nearly complete chlorine activation is seen inside the winter polar vortices. In the Antarctic, chlorine deactivation proceeds in a similar manner in both winters, with a rapid rise in HCl accompanying the decrease in ClO. In the Arctic, chlorine recovery follows different paths in the two winters: In 2004/2005, deactivation occurs through initial reformation of ClONO2 followed by slow repartitioning between ClONO2 and HCl, in agreement with the canonical view, whereas in 2005/2006, HCl and ClONO2 rise at comparable rates in some regions. The measurements are compared to customized runs of the updated SLIMCAT three-dimensional chemical transport model. Measured and modeled values typically agree well outside the winter polar regions. In contrast, as a consequence of the equilibrium scheme used to parameterize polar stratospheric clouds, the model overestimates the magnitude, spatial extent, and duration of chlorine activation inside the polar vortices.

21. The Tropical Ozone Tropopause Layer as Characterized from SHADOZ Data

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We present preliminary examples of SHADOZ ozone observations to distinguish a diverse mixture of ozone profiles in the tropical tropopause layer. The objective is to produce a definition, or a description of a reasonable method, from which to single out the tropical ozone tropopause given the different shapes encountered. Ozone profiles were found to vary in conjunction with changes occurring in the tropical tropopause layer (TTL). Various profile types, in the mean, are identified that appear reasonably coherent. There are a number of discussions in the literature addressing the TTL and ozone layer, we attempt only to provide a simple, but hopefully useful definition.

22. Observations of Stratosphere-Troposphere Exchange from the A-Train in 2006 During INTEX-B

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Studies of jet stream and frontal boundary dynamics with atmospheric tracer measurements provide insight to the coupled stratosphere-troposphere system. A-Train satellite instruments possess the horizontal and vertical resolution along with temporal and spatial coincidence necessary to identify stratospheric intrusions, investigate their three-dimensional structure, and estimate cross-tropopause exchange. We present results from our analysis of tropospheric chemistry and dynamics using AIRS and Aura instruments to observe stratospheric intrusions along the polar jet during the 2006 Intercontinental Chemical Transport Experiment Phase B (INTEX-B) field experiment. Focusing on April 2006, we explore the temporal and spatial evolution of an STE event over the western United States. With the broad swath of AIRS and the higher vertical resolution of Aura instruments like TES, ozone and water vapor retrievals show typical features of stratosphere-troposphere exchange in the UTLS. Analyses of in-situ and aircraft remote sensing measurements of these trace gases compare well with the satellite observations.

23. Performance of GEOS-5 in the Middle Atmosphere

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The Goddard Earth Observing System, Version 5 (GEOS-5) data assimilation system has been used to provide meteorological analyses for the EOS-Aura mission. Version 5.0.1 was run through the period July 2004; in late 2007 it will be replaced with Version 5.1.0 (and the Aura period will be reprocessed using this system). GEOS-5 analyses provide meteorological fields with a horizontal resolution of one-half degree latitude by two-thirds degree longitude on 72 layers, using a state-of-the-art general circulation model and a three-dimensional variation data assimilation scheme, with the incremental analysis update technique for smooth incorporation of observations into the analyses. Data constraints are from a large number of in-situ data and radiances from several polar orbiting satellites, including NASA's EOS-Aqua platform. This paper will discuss the accuracy of the analyses in the context of the Aura mission, focusing on the UTLS and the middle atmosphere. Validation techniques include comparison with independent observations and other analyses, as well as statistical comparisons of "forecast" and "observation" fields generated within the assimilation system. An important focus will be on improvements between GEOS-5.0.1 and GEOS-5.1.0.

24. Validation of the OMI Total Column Ozone Product: an Update

Richard McPeters (NASA/GSFC, Richard.D.McPeters@nasa.gov), M. Kroon and G. Labow

The total column ozone data products from the Ozone Monitoring Instrument (OMI) onboard the Aura satellite have been validated by comparison with various ground based and satellite data. Validation is primarily performed through comparison with a network of Dobson and Brewer ground stations, and secondarily through campaigns conducted specifically to validate Aura. Comparison with an ensemble of 76 northern hemisphere ground stations shows that OMI-TOMS total column ozone averages 0.4% higher than the station average, with station-to-station standard deviation of ±0.6%. The comparison shows that the OMI-TOMS ozone was stable over the two year period with no evidence of drift relative to the ground network. The OMI-DOAS product is also stable, but with a 1.1% offset and a seasonal variation of ±2%. During four aircraft validation campaigns using the NASA DC-8 and WB-57 aircraft, ozone comparisons showed agreement within 2% over a broad range of latitude and viewing conditions. The recently released corrected data from Earth Probe TOMS shows agreement with OMI within 1% on average but with up to 2% differences in mid to high latitudes in the northern hemisphere.

25. Aura Education and Public Outreach

Brooke Carter (NASA/GSFC/SSAI, brooke_carter@ssaihq.com) and S. Stockman

The Aura project supports a strong educational and public outreach (E&PO) effort through formal and informal education programs and partnerships with organizations that are leaders in science education and communication. Aura data are provided to the formal and informal educator in a meaningful context through the development of classroom lessons. Educators and students are able to pursue their own Aura-related

scientific investigations with scientific instruments that have been developed in conjunction with the GLOBE program. Visualizations of Aura data have been adapted for Science On a Sphere (SOS), a three-dimensional projection system that is installed in informal venues across the United States. Our goal is to educate students and the public and inform industry and policy makers how Aura will lead to a better understanding of the global environment.

26. New Aura Data Products Added to A-Train's Data Depot

Steve Kempler (NASA/GSFC, Steven.J.Kempler@nasa.gov), P. Smith, A. Savtchenko, G. Leptoukh, G. Stephens, and D. Winker

The A-Train Data Depot (ATDD) has been operational for over a year, successfully serving co-registered data from the Cloudsat, Calipso, AIRS, and MODIS instruments that are flying in succession along the A-Train flight path. Of late, OMI data products were added to the 'depot'. The objectives of the ATDD is to facilitate the goals of the A-train by; 1. Providing access to (eventually) all A-Train datasets, and; 2. Providing user friendly, quick data visualization and exploration to support science data discovery. In doing so, ATDD performs much of the work individual researchers would need to do, such as accessing remote datasets for convenient download, co-registering datasets, and performing these functions on specific user requested data of interest. The ATDD is a virtual data portal/center that processes, archives, provides access, visualizes, analyzes and correlates distributed atmosphere measurements from various A-Train instruments along A-Train tracks. Thus, the ATDD enables the free movement of remotely located A-Train data so that they can be combined to create consolidated vertical views of the Earth's atmosphere.

Recently several new products were added into the ATDD for data visualization and access generated by the OMI instrument. These include:
- OMI/Aura Effective Cloud Pressure and Fraction (Raman Scattering) (PI Joanna Joiner)
- OMI/Aura Effective Cloud Pressure and Fraction (O2-O2 Absorption) (PI Pepijn Veefkind)
- OMI/Aura Aerosol Extinction and Absorption Optical Depth (PI Omar Torres) (Parameters FinalAerosolOpticalDepth, FinalAerosolAbsOpticalDepth, UVAerosolIndex, Reflectivity)
- OMI/Aura Ozone (TOMS-like Algorithm) (PI P. K. Bhartia) (Parameters Aerosol Index)

In addition, the Cloudsat product, Radar-only liquid/ice water content (PI Dr. Richard Austin), was added to Giovanni and includes the parameters: Radar-only Liquid Effective Radius, Radar-only Ice Effective Radius, Radar-only Liquid Water Content, Radar-only Ice Water Content, Radar-only Liquid Water Path, Radar-only Ice Water Path. New CALIPSO profile parameters have been added, as well.

The ATDD makes much use of the innovative visualization and analysis tool, GIOVANNI, with the addition of vertical plots along the A-Train path, and horizontal strips that show products 100 km on either side of the path. Plots of selected products are displayed one under the other so that cross product relationships are easily identified.

Over 20 parameters of interest from OMI, Cloudsat, CALIPSO MODIS, and AIRS can be visualized and if desired, downloaded to your local computer for further analysis: Original and/or susbetted data granule. The ATDD can be found at: http://disc.gsfc.nasa.gov/atdd/

28. Photochemistry and Transport of Carbon Monoxide in the Middle Atmosphere Evaluated using Aura MLS

Ken Minschwaner (New Mexico Institute of Mining and Technology, krm@nmt.edu), G. L. Manney, N. J. Livesey, H. C. Pumphrey, H. M. Pickett, P. F. Bernath, and C. Boone

We present an analysis of the photochemistry and transport of carbon monoxide (CO) in the stratosphere and mesosphere using measurements from the Aura Microwave Limb Sounder (MLS) and the Atmospheric Chemistry Experiment-Fourier Transform Spectrometer (ACE-FTS). The distributions of many of the species involved in the photochemistry of CO are constrained from these two experiments, including OH, H2O, CH4, and O3. Observationally-based lifetimes of CO will be presented. Interactions between photochemistry and transport in stratopause region will be explored as they relate to the observed distribution of CO, and to the thermal structure and evolution of the stratopause.

29. Upper Stratospheric and Lower Mesospheric HOx: Theory and Observation

Tim Canty (University of Maryland, tcanty@atmos.umd.edu), H. Pickett, B. Drouin, K. Jucks, and R. J. Salawitch

Observations of OH and HO2 from the MLS instrument on Aura provide new insights into two long-standing scientific issues of middle atmosphere photochemistry: the ozone deficit problem and the HOx dilemma. The ozone deficit problem refers to the tendency of models to under-estimate observed ozone, in a region where the ozone photochemical time constant is short and where ozone is controlled by HOx photochemistry. The HOx dilemma refers to the fact that suggested kinetics changes needed to obtain good agreement with prior space-based observations of OH below ~40 km results in poorer agreement (relative to standard photochemistry) for comparisons in the upper stratosphere and lower mesosphere. We show, contrary to prior results, that the new measurements of HOx are well described by photochemical theory at all altitudes. However, an imbalance between production and loss of ozone persists for vast altitude regions, suggesting the middle atmosphere ozone budget is not “closed”. We shall focus on the relation between upper stratospheric and lower mesospheric O3, HOx, and H2O as observed by Aura MLS.

30. Comparison of OMI Measurements of Column BrO with Observations from GOME and Ground-Based Instruments

Ross Salawitch (University of Maryland, rjs@atmos.umd.edu), T. Kurosu, K. Chance, and K. Kreher

Quantification of atmospheric sources of BrO is an emerging issue in atmospheric chemistry. Observations indicate that supply of bromine from short lived, biogenic sources may impact the bromine budgets of both the troposphere and stratosphere. However, considerable uncertainties persist in quantification of the biogenic source strength. Global observations of BrO from OMI have the potential to reduce these uncertainties. Here, we compare observations of column BrO from OMI to ground based observations from a variety of locations, as well as a climatology from GOME. These comparisons will serve as a step in the validation of column BrO from OMI.

31. Optimally combining ozone from Tropospheric Emission Spectrometer (TES) and Ozone Monitoring Instrument (OMI) data

Susan S. Kulawik (Jet Propulsion Laboratory, Susan.S.Kulawik@jpl.nasa.gov), X. Liu, J. R. Worden, K. Chance, K. Bowman, and the TES team

We show results from joint TES-OMI retrievals for May, 2006. We combine TES and OMI data using both optimal averaging of the individual profile retrieval results from OMI and TES, and by linear updates from the spectral residuals. Combined retrievals from the UV and IR spectral ranges have previously been shown to result in increased tropospheric sensitivity and resolution, and of particular interest, increased sensitivity to the planetary boundary layer. Results are compared to the OMI and TES results, and to near by sondes.

32. Local CO enhancements in the upper troposphere: examining data from TES, MLS and MOPITT

Ming Luo (Jet Propulsion Laboratory, Ming.Luo@jpl.nasa.gov), G. Osterman, N. Livesey, J. Jiang, and L. Jourdain

We focus on selected CO enhancement events observed in TES data and also examine MLS and MOPITT data in the upper and lower troposphere. The events of interest include: the Siberian fires in July-Aug 2006, Indonesian fires in Sept-Oct-Nov 2006, Australian fires in mid-end Dec 2006 and the transpacific transports of pollutants in winter-spring 2007. The CO distributions near the event regions observed by the three instruments provide good opportunities for cross-instrument and cross-platform validations of the datasets. We describe the advantages, the limitations and the influence of the a priori assumptions to the retrievals for the nadir and limb instruments. The combination of the nadir and limb observations of CO provides a powerful datasets for studying pollution transport in different regions of the globe. Trajectory models are used to track the origins of the enhanced CO at different levels of the troposphere.

33. Water vapor in the Arctic lower stratosphere and upper troposphere

Rigel Kivi (Finnish Meteorological Institute, Arctic Research Centre, rigel.kivi@fmi.fi) and H. Vömel

During the Arctic winters of 2005/2006 and 2006/2007 a series of balloon borne cryogenic frost point hygrometers (CFH) were flown in Sodankylä, Finland (67.4 ºN, 26.6 ºE). Here the coincident polar measurements are compared with the Aura Microwave Limb Sounder (MLS) water vapor measurements. In addition to the single CFH sonde flights we made a series of comparison flights, which included the CFH and two versions of Vaisala RS92 radiosonde. The comparisons showed that the radiosondes have a dry bias during the daytime soundings of the order of 20% in the upper troposphere at 300 hPa. The new version of the RS92 radiosonde is available since September 2006. Our multiple sonde flights suggest that the use of the new version of the RS92 reduces the dry bias in the upper troposphere compared to the older model of the RS92.

34. Studying the upper tropospheric ozone enhancements over North America: Analysis with TES observations and FLEXPART

Annmarie Eldering (Jet Propulsion Laboratory/Caltech, Annmarie.Eldering@jpl.nasa.gov), S. S. Kulawik, and O. Cooper

The Tropospheric Emission Spectrometer on the EOA Aura satellite provides global measurements of vertically resolved ozone. During the summer of 2006, an observation campaign was conducted by TES to make 25,000 profile measurements over North America and the Atlantic. This dataset is used with the FLEXPART Lagrangian particle dispersion model to explore the features of upper tropospheric ozone over North America, and to study the influence of long-range transport and in-situ ozone formation, and to compare to similar analysis that have utilized summer ozonesonde data. Specifically, this presentation will focus analysis of the ozone over the southeastern US during August 2006, and compare the analysis using TES measurements to the conclusions reached with the IONS ozonesondes.

35. Intercomparisons of Aura MLS, ACE, and HALOE observations of long-lived trace species using the LaRC Lagrangian Chemistry and Transport Model

David Considine (NASA Langley Research Center, david.b.considine@nasa.gov)

We use the NASA Langley Research Center Lagrangian Chemistry and Transport Model (LCTM), initialized with Atmospheric Chemistry Experiment (ACE) measurements, to evaluate Aura MLS measurements of O3, H2O, HCl, and N2O. We find generally good agreement between the ACE species and MLS. This contrasts with HALOE-Initialized LCTM comparisons, where HCl and H2O display low-biases with respect to MLS. We also examine the implications of the ACE sampling pattern for trajectory model-based investigations of atmospheric composition.

36. Validation of HIRDLS Ozone [v2.04.08]

Bruno Nardi (NCAR, Atmospheric Chemistry Division, nari@ucar.edu), J. C. Gille, J. J. Barnett, C. E. Randall, V. L. Harvey, A. Waterfall, W. J. Reburn, T. Leblanc, T. J. McGee, S. Godin-Beekmann, A. M. Thompson, B. Bojkov, D. N. Whiteman and the HIRDLS Team

Comparisons of the latest HIRDLS ozone retrievals (v2.04.08) are made with ozonesondes, ground-based lidars, air-borne lidar measurements made during INTEX-B and satellite observations. A large visual obstruction blocking over 80% of the HIRDLS field-of-view, presents significant challenges to the data analysis methods and implementation, to the extent that the radiative properties of the obstruction must be accurately characterized in order to adequately correct measured radiances. HIRDLS ozone compared here is retrieved from radiances produced with the latest correction algorithms as of August 2007. Comparisons indicate that HIRDLS ozone is recoverable between 1 hPa – 100 hPa at mid and high latitudes and between 1 – 50 hPa at low latitudes. Accuracy of better than 10% is indicated between 1 - 30 hPa (HIRDLS generally low) by the majority of the comparisons with coincident measurements, and 5% is indicated between 2 - 10 hPa when compared with some lidars. Between 50-100 hPa, at mid and high latitudes, accuracy is 10-20%. The ozone precision is estimated to be

generally 5% to 10% between 1 - 50 hPa. Comparisons with ozonesondes and lidars give strong indication that HIRDLS is capable of resolving fine vertical ozone features (1 - 2 km) in the region between 1 - 50 hPa. Development is continuing on the radiance correction and the cloud detection and filtering algorithms, and it is hoped that it will be possible to achieve a further reduction in the systematic bias, and an increase in the measurement range downward to lower heights (at pressures greater than 50-100 hPa).

37. Quantifying the deep convective flux of CO into tropical upper troposphere: A modeling analysis of Aura-MLS CO Measurements

Chenxai Cai (Jet Propulsion Laboratory/CalTech, chenxia.cai@jpl.nasa.gov), N. Livesey, Q. Li and J. Waters

Dramatic enhancement of CO over the Amazon was observed by Aura-MLS at 147 hPa during September-October 2005. It is known that widespread deep convection in the tropics can efficiently deposit surface biomass burning emissions in the upper troposphere. Using 5-day running averages of MLS CO at 1-day interval, we estimated the convective vertical CO fluxes by subtracting the horizontal flux terms and net chemical production/loss from total CO tendency. Our results suggest that the abrupt enhancement of the 147 hPa CO concentrations over the Amazon is associated with the dramatic increase of deep convective CO fluxes. This conclusion is supported by CO fluxes derived from the GEOS-Chem global 3-D chemistry and transport model results simulated for the same time period. The model is driven assimilated meteorological data and includes 2005-specific biomass emissions constrained by satellite observations. Model results show consistent spatiotemporal distributions as the MLS-derived CO fluxes. The increase in the deep convective CO fluxes during September-October 2005 are further investigated by examining MODIS fire counts and MLS cloud ice data (ice water content), indicators for the intensity of biomass burning and deep convection, respectively, for the corresponding period. The strength of deep convection during the aforementioned time period is also examined using NCEP convective mass flux.

38. Atmospheric Chemistry Experiment: Summary of Recent Stratospheric and Upper Tropospheric Results

Curtis Rinsland (NASA Langley Research Center, curtis.p.rinsland@nasa.gov), P. Bernath and C. D. Boone

The Atmospheric Chemistry Experiment (ACE), also known as SCISAT-1 is a Canadian lead satellite mission focused on remote sensing of the Earth's atmosphere. It was launched into a 74 degree inclined orbit at 650 km altitude by a NASA-supplied Pegasus launcher on 12 August 2003. The instrument operates primarily in solar occultation mode with measurements at 85 degree N latitude to 85 degree S latitude. The primary instrument is a high spectral resolution (0.02 cm-1) Fourier transform spectrometer, and we summarize recent results in the upper troposphere and stratosphere from that instrument including first satellite detections of several species.

39. Development of new near-real-time data products from the Aura Microwave Limp Sounder

Alyn Lambert (Jet Propulsion Laboratory, Alyn.Lambert@jpl.nasa.gov), W. G. Read, L. Froidevaux, M. J. Schwartz, N. J. Livesey, P. A. Wagner and D. Cuddy

Development of new near-real-time data products from the Aura Microwave Limb Sounder We describe our plans to develop new data products from an Aura Microwave Limb Sounder (MLS) Near-Real-Time (NRT) data stream that can be assimilated by operational analysis schemes. Several partners within the Joint Center for Satellite Data Assimilation (JCSDA) have expressed an interest in assimilating the MLS ozone, temperature and water vapor data. The goal is to decrease the mean analysis error and the standard deviation for these fields and thereby (a) decrease the residuals of the assimilated satellite radiance data, (b) improve the temperature analyses by providing the radiation scheme with more accurate radiative heating rates and (c) improve wind analyses in the upper troposphere and lower stratosphere through correlations with tracers. Preliminary retrievals using a limited number of channels of the the MLS 240-GHz band and a fast forward model have shown the potential for obtaining a high quality ozone product throughout the stratosphere and upper troposphere down to 215 hPa with dramatically reduced computational resource requirements compared to the production of the Aura MLS standard ozone product.

40. The First Multi-Constituent Kalman Filter Analysis of Atmospheric Chemistry from 1991-2007

David Lary (UMBC/GEST and NASA/GSFC, David.Lary@umbc.edu)

This study presents the first 16 year multi-constituent chemical analyses produced by a full Kalman filter. It is global from the surface to the upper stratosphere. Daily solar irradiance values are used, observed sulfate aerosol areas and radii from UARS HALOE, and constituent observations of O3, H2O, CH4, HNO3 and HCl from UARS, ATMOS, CRISTA, MkIV, ILAS, Aura, SAGE, SBUV, POAM, Mozaic, Sondes and aircraft. The analyses are available on line at www.CDACentral.info. They are being used for a variety of purposes from NASA Aura validation to understanding of the interactions between the distributions of ozone, water vapor, aerosols, temperature, and relevant trace constituents, notably chlorine and bromine compounds and nitrogen oxides. A particular interest has been under standing the role of halogens in hydrocarbon oxidation in the upper free troposphere.

41. Aura Bias detection and correction: A neurological approach

David Lary (UMBC/GEST and NASA/GSFC, David.Lary@umbc.edu)

We present an end-to-end approach for inter-instrument bias detection and correction. The bias detection uses large sample sizes and probability distribution functions. The bias correction uses multi-variate, non-linear, non-parametric neural networks. Neural networks are universal approximators and have provided very effective in inter-instrument bias correction.

42. Tropical Tropospheric Ozone Measured from AURA

Mike Newchurch (UAH, mike@nsstc.uah.edu), J. H. Kim, S. Kim, M. Luo, R. Martin, and B. Sauvage

Our presentation focuses on evaluation and analyses of the following three tropospheric ozone products derived from AURA measurements: TES retrievals, tropospheric ozone residual between OMI total ozone and MLS stratospheric ozone (OMI-MLS), and OMI scan angle measurement (SAM). Rather than using the typical station-to-station intercomparison with ozonesounding measurements, we study the global perspective of temporal and spatial patterns derived from Empirical Orthogonal Function (EOF) and Singular Value Decomposition (SVD) analyses. GEOS-CHEM model products and MOPITT CO serve as markers are identifying the times and locations of biomass burning. These analyses identify the coupled relationships with spatial-temporal pattern between each ozone product and biomass-burning proxies. Tropospheric ozone products determined from AURA satellite were also compared with those determined from Earth Probe TOMS. These analyses suggest that there are significant differences in derived tropospheric ozone between retrieval methods.

43. Total NO2 columns from ground-based direct-sun measurements with three different instruments at three locations versus OMI/AURA retrievals

Alexander Cede (NASA/GSFC, alexander.cede@gsfc.nasa.gov), E. Spinei, T. Pongetti, N. Abuhassan, B. Bojkov, S. Sander, G. Mount, and J. Herman

We compare total NO2 columns from ground-based direct sun measurements by two CCD array spectrometers and one Fourier transform UV spectrometer to retrievals from OMI/AURA under normally clean conditions at the JPL-Table Mountain Facility, California during early July 2007. In addition, the two CCD spectrometers, PANDORA (GSFC) and MF-DOAS (WSU) are compared to OMI/AURA at the urban site Goddard Space Flight Center, Maryland, May 2007. The excellent agreement between PANDORA and the MF-DOAS reference instrument lends confidence to the direct-sun measurements. We also present data obtained at the urban Thessaloniki, Greece, site from PANDORA in July 2006. Systematic differences between ground and satellite data have three possible origins: 1) differences in slant column measurements due to instrument calibration, fitting windows, cross sections, etc., 2) differences in the conversion from slant column to vertical column due to different air mass factor calculations, and 3) differences in the sampled viewing area. Item 1 usually accounts for <10%, items 2 and 3 can produce much larger differences. In contrast to scattered light measurements, the air mass factor for direct-sun measurements is easily computed only marginally depends on the vertical NO2 column, surface albedo and aerosols. Therefore, differences from the satellite data can be attributed nearly entirely to uncertainties in the air mass factor estimation from space and to the different viewing geometry.

44. Comparison of HIRDLS and ECMWF ozone and temperature data

Alison Waterfall (Rutherford Appleton Laboratory, A.M.Waterfall@rl.ac.uk), W. J. Reburn, B. Kerridge, and the HIRDLS team

In this presentation we will show the results of a comparison between the latest ozone and temperature products from HIRDLS and those from the European Centre for Medium-Range Weather Forecasts operational analysis. The ECMWF data are available on 60/91 model levels up to 0.1/0.01 hPa (depending on the time period) at standard synoptic times, and these have then been interpolated in space and time to the locations of the HIRDLS profiles. Radiative transfer simulations using this data have also been compared to the appropriate HIRDLS radiances. The HIRDLS instrument has now recorded data for a period of almost 3 years from January 2005. This comparison will concentrate on a subset of selected days over this whole time period. These comparisons are useful tools in the validation of HIRDLS data, allowing comparisons of the whole global dataset, and illustrating the good consistency present in the HIRDLS data over time. Such comparisons can also highlight limitations of the ECMWF data.

45. Comparison of tropospheric/total NO2 columns from OMI/Aura and ground-based scattered sky/direct sun measurements using the WSU Multi-Function Differential Optical Absorption Spectrometer over Goddard Space Flight Center and Jet Propulsion Laboratory-Table Mountain Facility in summer 2007

Elena Spinei (Washington State University, espinei@wsu.edu), E. Spinei, G. H. Mount, S. Sander, J. Herman, A. Cede, and T. Pongetti

Ground-based tropospheric and total NO2 columns were measured in the polluted airshed over Goddard Space Flight Center in May 2007 and near the Los Angeles basin at the Jet Propulsion Laboratory Table Mountain Facility in July 2007. We compare Aura/OMI total/tropospheric NO2 with direct sun/scattered sky measurements from the WSU MFDOAS instrument. NO2 differential slant column densities (DSCD) derived from the scattered sky DOAS observations were converted to vertical column densities using the LIDORT v.3.3 scalar radiative transfer model while the direct sun air mass factors were computed directly. The combination of direct sun measurements with the simple geometric AMF and scattered sky measurements with the strong tropospheric absorbance enhancement, gives higher confidence in the derived results.

46. Retrieval of NO2 absolute columns in the stratosphere and troposphere from ground-based UV-visible measurements with the Fourier Transform Ultraviolet Spectrometer (FTUVS) at Table Mountain, California: Method and comparison to OMI.

Stanley Sander (Jet Propulsion Laboratory, ssander@jpl.nasa.gov), T. Pongetti (presenter), C. M. Chen, M. M. Marinova, and Y. L. Yung

We describe the retrieval method of stratospheric, tropospheric, and total NO2 absolute vertical columns from the direct sun measurements using the Fourier Transform Ultraviolet Spectrometer (FTUVS) at Jet Propulsion Laboratory's Table Mountain Facility (TMF). High resolution (resolving power of 400,000) spectra are acquired which permit individual NO2 rovibronic features to be resolved. The method uses the east/west Doppler ratio technique to attenuate solar lines. Information on the vertical profile of

NO2 is derived from the analysis of pressure-broadened line shapes. Column amounts from various spectral windows are compared for consistency then averaged to derive the stratospheric and tropospheric partial column abundances. Results dating from April 2005 to present are compared with results from OMI.

47. Validation of HIRDLS Version 2.04.08 Temperature Data

John Gille (UCAR, gille@ucar.edu), J. Barnett, A. Waterfall, B. Nardi, C. Randall, L. Harvey, R. Khosravi, J. Reburn, S. Massie, C. Cavanaugh, J. Craft, C. Hepplewhite, C. Craig, V. Dean, T. Eden, G. Francis, C. Halvorson, D. Kinnison, C. Krinsky, H. Lee, and G. Young

The HIRDLS Version 2.04.08 Temperature Data have been validated through comparisons with high resolution radiosondes, ECMWF analyses, lidars, ACE occultation soundings, GPS soundings and other data. Comparison with ECMWF analyses shows that there has been no drift over the 30 months of data. Comparisons with all data sources indicate biases < ±2K from ~ 300 mb up to 1 mb. The precision has been estimated by several methods. It is a minimum near 20 km, and increases above and below this level. One difficulty is that HIRDLS' sensitivity to small vertical scales, which are not detected by conventional data sources, may cause the precision in the upper stratosphere and above to be overestimated.

48. Evidence of near-zero ozone in thick clouds from OMI measurements

Sushil Chandra (UMBC/GEST and NASA/GSFC, sushilchandra@comcast.net), J. R. Ziemke, P. K. Bhartia, J. Joiner, A. Vasilkov, and L. Froidevaux

Ozonesonde measurements in the tropics often show exceedingly low to near-zero O3 concentrations in the upper troposphere. These low concentrations are largely attributed to vertical injection from convective clouds in oceanic regions of low amounts of boundary layer O3 followed by convective outflow. This investigation uses tropical O3 and cloud pressures from the Aura Ozone Monitoring Instrument (OMI) to study this atmospheric phenomenon. The OMI data provide unique in situ (in cloud) measurements of O3 lying within thick convective clouds. Results show that near-zero O3 in thick clouds is a common occurrence throughout the remote Pacific. This is not the case for thick clouds over landmasses of South America and Africa where values ~30-50 ppbv suggests a polluted environment and elevated amounts of boundary layer O3.

49. Last Year's Progress with the Aura MLS OH and HO2 measurements

Herbert Pickett (Jet Propulsion Lab, herbert.m.pickett@jpl.nasa.gov), T. Canty, R. Salawitch, S. Wang, S. Sander, and N. Livesey

The Aura MLS instrument measures OH near 2512 GHz and HO2 near 660 GHz. We will present results with the new v2.2 retrieval program. Both OH and HO2 measurements have been validated in Sept. 2004 and Sept. 2005 using the balloon-borne BOH, FIRS-2 and SLS instruments. Ground-based OH column measurements show good agreement with integrated columns derived from MLS OH profiles. A photochemical model for OH and HO2 concentrations compares very well with the MLS profiles. Comparison with MAHRSI OH shows a much diminished "HOx dilemma".

50. Morphology of 2005-2007 NH polar winter wave dynamics as seen by the HIRDLS instrument

Valery Yudin (UCAR, vyudin@ucar.edu), J. C. Gille, R. Khosravi, and the HIRDLS Science Team.

This paper presents analysis of 2005-2007 NH polar winter wave dynamics as observed by the HIRDLS instrument. The high resolution vertical probing of stratosphere by HIRDLS gives opportunity to examine capability of space-borne instruments to provide new information on the small-scale waves especially during stratospheric warming events. Along with breaking of planetary scale oscillations these waves can play significant role in the vertical layer coupling. As speculated by modeling studies, short-scale gravity waves change the stratospheric circulation patterns and accompany establishment of new polar vertical temperature structures during the strong major warming events. The morphology of planetary waves and residual short-scale oscillations from HIRDLS temperature and ozone data will be discussed for Jan 2005-2007. The temperature and ozone HIRDLS retrievals will be compared to MLS, SABER retrievals and GEOS5 analyses. The analyzed GEOS5 wind fields are employed to interpret geographical patterns of observed short-scale oscillations associated with gravity wave propagation. In the NH polar regions of upper stratosphere and mesosphere there are noticeable persistent differences between GEOS5 temperatures and space-borne retrievals. In this region, during major warming days the deviation of GEOS5 temperatures from satellite data becomes larger compared to the unperturbed winter conditions.

51. Spring to summer northward migration of high O3 over the western North Atlantic

Yunsoo Choi (Georgia Institute of Technology, yunsooc@gmail.com), Y. Wang, Q. Yang, D. Cunnold, T. Zeng, C. Shim, M. Luo, A. Eldering, E. Bucsela, and J. Gleason

Tropospheric O3 columns retrieved from OMI and MLS measurements, NO2 columns from OMI, and upper tropospheric O3 concentrations from TES over North America and the western North Atlantic from April to August 2005 are analyzed using the Regional chEmical and trAnsport Model (REAM). Large enhancements of column and upper tropospheric O3 over the western North Atlantic comparable to those over the eastern United States are found in the satellite measurements and REAM simulations. The O3 enhancement region migrates northward from spring to summer. Model analysis indicates that the northward migration is driven by seasonal shifts of O3 transported from the stratosphere and that produced through photochemistry from surface emissions and lightning NOx. As their uncertainties improve, satellite measurements of O3 and its precursors will be able to provide more quantitative constraints on pollutant outflow from the continents.

52. Long-range pollution transport and continental US air quality during the 2006 INTEX-B and TEXAQS field missions

Jay Al-Saadi (NASA Langley Research Center, j.a.al-saadi@nasa.gov), B. Pierce, J. Szykman, T. Schaack, K. Bowman, M. Avery, G. Sachse, A. M. Thompson, B. Lambeth, D. Jaffe, P. K. Bhartia, J. Gleason, C. Boone, C. Rinsland, T. Ryerson, J. Holloway, T. Campos, A. Weinheimer, and L. Emmons

This talk presents a summary of studies utilizing the Real-time Air Quality Modeling System (RAQMS) to characterize trans-pacific pollution transport, photochemistry and continental US air quality during the 2006 NASA INTEX-B and NOAA TEXAQS field missions. The RAQMS chemical analysis includes assimilation of cloud cleared OMI total column ozone measurements and ozone and carbon monoxide profiles from TES nadir global survey measurements. The chemical analyses are used in conjunction with airborne, surface and satellite measurements to show evidence of upper tropospheric pollution fluxes and efficient mixing of polluted and stratospheric air masses over the central pacific, and enhanced pollution along the west coast of the US. Non-coincident satellite validation studies (using the RAQMS chemical analysis as a transfer standard between asynchronous satellite and airborne measurements) show that OMI and MOPITT overestimate tropospheric NO2, O3, and CO amounts relative to airborne measurements. These apparent discrepancies are interpreted in light of surface measurements from the US EPA, Mount Bachelor Observatory, and TCEQ.

53. What have we learned about global SO2 sources with OMI data?

Nickolay Krotkov (UMBC, Krotkov@mhatter.gsfc.nasa.gov), S. Carn, A. Krueger, K. Yang, and P. K. Bhartia

Sulfur Dioxide (SO2) is a short-lived gas primarily produced by volcanoes, power plants, refineries, metal smelting and burning of fossil fuels. Emitted SO2 is soon converted to sulfate aerosol, which can have climate effects, including direct radiative forcing and aerosol-induced changes in cloud microphysics. The exceptional dynamic range of atmospheric SO2 loading (from < 0.1DU in pollution to > 1000DU in explosive volcanic eruptions) presents unique challenges for operational satellite monitoring. The Ozone Monitoring Instrument (OMI) launched on NASA Aura satellite in July 2004 offers unprecedented spatial resolution, coupled with contiguous daily global coverage, for space-based UV measurements of SO2. Optimum wavelength selection results in 20-fold higher sensitivity than the predecessor TOMS instruments. This allows quantification of the SO2 tonnage from volcanic degassing and eruptions, including Merapi (Indonesia), Tungurahua (Ecuador), Rabaul (Papua New Guinea), Piton de la Fournaise (Reunion), Soufriere Hills (Montserrat), Aoba (Vanuatu), Nyiragongo (DR Congo) and Ubinas (Peru). The eruption of Soufriere Hills volcano (Montserrat) on May 20, 2006 resulted in a stratospheric injection of ~0.2 Tg of SO2. Despite the modest size of the SO2 cloud (2 orders of magnitude lower in mass than Pinatubo), OMI was able to track it for over 3 weeks and ~16,000 miles as it traveled westwards from the volcano. Near-coincident CALIPSO lidar measurements of the subsequent stratospheric sulfate aerosol demonstrates the value of joint A-Train observations of volcanic clouds. OMI SO2 measurements also played a key role in diagnosing the nature of activity at Fourpeaked volcano (Alaska), during its first historical eruption in September 2006, and permitted the dating of an unwitnessed submarine eruption of Home Reef (Tonga) in August 2006.

Anthropogenic SO2 emissions in the PBL present challenges, because these typically weak signals need to be separated from the noise in the radiances. Spatial smoothing and/or time averaging allow significant signal to noise enhancements. Applying these techniques, power plant emissions in Greece, Bulgaria, Turkey, and the US Ohio river valley can be seen in OMI data as well emissions from Persian Gulf refineries, and pollution plumes in a Mexico city area industrial complex. Unknown sources are also being identified. Using long-term averages anthropogenic SO2 burdens can be compared directly in different parts of the world. Strong SO2 emissions from Peruvian copper smelters and Chinese industrial sources and power plants can be detected in daily data. Operational data were confirmed with in-situ aircraft SO2 profiles measured in the lower troposphere over China during the East Aire campaign in April 2005. Chinese SO2 pollution lofting above the PBL and long-range transport over Pacific Ocean was first confirmed using OMI data.

54. Views of North American Tropospheric Lower Ozone from IONS Soundings and an Evolving OMI-Ozone/AIRS-Dynamics Technique for March-May and August, 2007

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Lower tropospheric ozone deserves concerted efforts, as it affects air pollution forecasting and control, and as it effects hemispheric pollution and climate; we report on progress and some evidence that we may expand expectations. The IONS (INTEX [Intercontinental Transport Experiment] Ozonesonde Network Study) periods of intensive investigation which included a March-May, 2007, a NASA-intensive period as well as August, 2007, a NOAA-State of Texas intensive period, provided suborbital data useful in characterizing time and space variation of lower tropospheric ozone as well as a data rich period for evaluating tropospheric ozone. We provide a time-space interpolating analysis of lower tropospheric ozone from sondes in animation and technical form. We venture an explanation the particular difficulties of using satellite information in the Southwestern US, and contrast both the meteorology of ozone and its sensing with the Southeastern US, where tropospheric ozone residuals have long appeared to be appealing. In this limited sample, the Schoeberl et al. (2007) OMI-MLS technique did exceptionally well with lower tropospheric ozone, but very poorly with the smog layer. This is not surprising, the residuals poorly correlate with the surface ozone measurements because of the low sensitivity of the UV retrievals to boundary layer ozone and the fact that boundary layer ozone is a small fraction of the column - usually within the uncertainty of the total column and the MLS stratospheric column. These periods also allow an initial report of a technique using ozone column from only one instrument, OMI, but powerfully aided by atmospheric structure information (theta, dT / dz) from near-simultaneous AIRS observations. Comparative animations of the special periods and connections with TES and AIRS ozone-sensing capabilities will be described as time allows.

55. Assimilation of Aura-MLS CO and O3 data in the UTLS with the MOCAGE-PALM system to study the impact of pollution transport in the UT during the West African monsoon.

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The Aura-MLS spaceborne sensor provides unprecedented observations of the chemical composition of the Upper Troposphere-Lower Stratosphere. We have assimilated the latest (V2.2) Aura-MLS CO and O3 data in the MOCAGE Chemistry Transport Model using the PALM coupler and a 3DFGAT method. We will present results for the 2006 boreal summer period that corresponds to the intensive observation period of the African Monsoon Multidisciplinary Analyses (AMMA) project. We will in particular show comparisons between the assimilated fields and the airborne in-situ MOZAIC Air-Namibia CO and O3 data which provide information about the upper troposphere (UT) in a latitudinal transect between Windhoek (Namibia) and Frankfurt (Germany) around 200 hPa. The coupling between model and observations provides realistic upper tropospheric 4D CO and O3 fields that allow the quantification of transport and chemical processes that affect this region. Of particular importance is the high altitude (100-200 hPa) Tropical Easterly Jet (TEJ) which transports air masses from South Asia across the Indian Ocean to Africa and further to the Atlantic Ocean. We will use the 4D assimilated fields to assess the relative impact of the TEJ and of convective processes that uplift air masses affected by local surface processes on the composition of the UT over Western Africa during the monsoon.

56. Test Results from Assimilation of NRT MLS Ozone Profile Data in the NCEP GFS

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The MLS team has modified their processing to create near-real-time (NRT) ozone and temperature products for use by the operational meteorological community. We will present the benefits of assimilation of MLS ozone in to the NCEP GFS. We will then discuss the differences between the V2.2 and the NRT products and what how these differences impact assimilation results.

57. Comparison of OMI and ground based in situ and MAX-DOAS measurements of tropospheric NO2 in an urban area.

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Monitoring urban air quality is an important issue and remotely sensed data from ground and space based instruments are being extensively used to measure NO2 levels over urban and regional areas. Global NO2 data have been retrieved from measurements performed by the Ozone Monitoring Instrument (OMI), launched onboard the NASA satellite Aura in July 2004. The relatively high spatial resolution of OMI should make it suitable for measurements of air quality on an urban scale. Here, we present a comparison and validation of tropospheric NO2 retrievals from OMI with data from an in situ set of Chemiluminescence detectors and a ground based UV/Visible Concurrent Multi Axis Differential Optical Absorption Spectroscopy (CMAX-DOAS) instrument. The

Chemiluminescence detectors are located in urban and rural areas around Leicester, whilst the CMAX-DOAS instrument is based within the urban area. The results show that NO2 emissions from a polluted urban area cannot be simplistically linked to the column measurement by a satellite instrument. More encouragingly, we can demonstrate a FOV-weighted correction to obtain a relationship between column measurements of NO2 from satellites to those at near-surface. The agreement between the OMI tropospheric VCDs and FOV-weighted near-surface measurements is very good for spring and summer months, however, OMI appears to be underestimating the NO2 level during winter. Finally, the FOV-weighted and OMI weekly NO2 cycles both show the "weekend effect", with high values mid-week and significantly lower values on a Sunday.

58. Compatibility and Synergy Analysis on the Aerosol Products Derived from Aura/OMI and Aqua/MODIS

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In this paper, we compare the aerosol products derived from Aura/OMI and Aqua/MODIS based on the operational retrieval algorithms for both daily level 2 as well as monthly level 3 data. Although the nature of two products differs in many regards, such intercomparisons render a great potential for developing an integrated product of considerable value for climate studies. Presented in this paper are some preliminary results of inter-comparison, synergy analysis, and validation against ground-based aerosol data from the AERONET. The dataset under study include aerosol optical thickness (AOT), Angstrom exponent, single scattering albedo (SSA), and Aerosol Index (AI). The compatibility and consistency between the two aerosol products focused on AOT and SSA will be discussed based on both regional and global scales. Possibility of acquiring synergistic information about aerosols by combining the information from the two aerosol products is also being sought in this study.

59. Extending the satellite record of total ozone measurements using OMI

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The continuous global record of total ozone measurements begins in late 1978 with the TOMS and SBUV instruments on Nimbus 7. The record has been continued with the series of SBUV/2 instruments on the NOAA polar-orbiting satellite series and with the Earth Probe TOMS instrument. We now extend that record into mid-2007 including data from the OMI instrument on Aura. This record can be used for time-series analysis to determine the sensitivity of stratospheric ozone to the addition of chlorine and bromine containing species. The key to such a record is the intercalibration among different satellite instruments and the removal of any potential sources of drift of individual instruments. We demonstrate how the shorter wavelengths of the SBUV measurements have been used to stabilize the record against drift and how the overlaps of the various instruments have been used to maintain a uniform calibration. The OMI instrument now extends the daily global mapping capability of the TOMS instruments and gives us a long record to look for key fingerprints of ozone change and recovery.

60. Impact of MLS Signal-Chain Nonlinearity on Retrieved Temperature: A First look

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The nonlinearity of MLS intermediate frequency (IF) amplifiers has been estimated from laboratory analyses of spare flight hardware at Jet Propulsion Laboratory. The impact of such nonlinearity upon MLS retrieved temperature was estimated during version 2 temperature validation by comparing retrievals run on two sets of simulated MLS radiances, one with and one without the nonlinearity. This nonlinearity was identified as the largest source of systematic error in MLS version 2 temperature. The work described here is an initial attempt to correct observed radiances for this nonlinearity and to examine the impact on retrieval radiance residuals, and upon the temperature product. The nonlinearity is modeled as a gain compression, which is a function of total signal power, and which must be estimated from measurements of the limited portions of the IF band where spectrometers make measurements.

61. Observed and Modeled HOCl Profiles in the Midlatitude Stratosphere: Implication for Ozone Loss

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The HOCl catalytic cycle for ozone loss is important in the mid-latitude stratosphere. We use a diurnal steady-state photochemical model to calculate profiles of HOCl for conditions sampled by two high-altitude balloon-borne instruments, MkIV (a mid-infrared, solar absorption spectrometer) and FIRS-2 (a far-infrared emission spectrometer). To assess how well this model represents ozone loss by the HOCl cycle, we compare our calculations of HOCl and its precursors, ClO and HO2, with measurements obtained by MkIV, FIRS-2, a submillimeterwave limb sounder (SLS), and Aura MLS. We then evaluate these comparisons in light of a number of recent laboratory studies of the main formation mechanism of HOCl, the reaction of ClO + HO2. Preliminary comparisons between model and observations suggest better agreement might be achieved with a faster rate constant. Now that the spectroscopy behind the remote sensing observations are consistent, and the balloon datasets are all consistent with each other, we use them to evaluate the accuracy of MLS retrievals of HOCl in the upper stratosphere.

62. Connecting surface emissions, convective uplifting, and long-range transport of carbon monoxide in the upper-troposphere: New observations from the Aura Microwave Limb Sounder

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Two years of observations of upper tropospheric (UT) carbon monoxide (CO) from the Aura Microwave Limb Sounder are analyzed; in combination with the CO surface emission climatology and data from the NCEP analyses. It is shown that spatial

distribution, temporal variation and long-range transport of UT CO are closely related to the surface emissions, deep-convection and horizontal winds. Over the Asian monsoon region, surface emission of CO peaks in boreal spring due to high biomass burning in addition to anthropogenic emission. However, the UT CO peaks in summer when convection is strongest and surface emission of CO is dominated by anthropogenic source. The long-range transport of CO from Southeast Asia across the Pacific to North America, which occurs most frequently during boreal summer, is thus a clear imprint of Asian anthropogenic pollution influencing global air quality.

63. Raman Water Vapor Lidar Based Calibration Studies during MOHAVE and WAVES.

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Atmospheric water vapor profiling from high altitude sites using Raman Lidar is one of the measurement goals of the NDACC (Network for the Detection of Atmospheric Composition Change). These NDACC sites offer large volumes of data for satellite validation as well. Accurate calibration of Raman water vapor lidars is of obvious importance in these activities. A well calibrated Raman Lidar can also be used to quantify water vapor and cloud variability in the troposphere where the underlying dynamics leading to the observed water vapor distribution is revealed. Such calibration is often performed by comparison with quality-controlled radiosonde data. However, the inherent spatio-temporal mismatch between lidars (which measures along the laser beam and require longer averaging times as altitude increases) and radiosondes (which float with the wind and have roughly the same measurement statistics with altitude) presents significant additional challenges in data processing. We review Raman water vapor lidar calibration techniques and illustrate data-processing techniques that help address these challenges. We use measurements from the MOHAVE field campaign at the JPL/Table Mountain Facility in October, 2006 and the WAVES field campaign at the Howard University facility in the summer of 2006 and 2007.

64. Using Aura MLS and CALIPSO measurements to constrain simulations of transport, convective injection, cloud formation, and water vapor in the tropical tropopause layer

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Numerous studies over the past several years have focused on simulations of cloud formation and dehydration in air ascending through the tropical tropopause layer (TTL). However, uncertainties in microphysical processes, vertical ascent rates, and the importance of convective influence have been difficult to resolve with available water vapor datasets and (mostly limb-viewing) satellite observations of TTL cirrus. With the CALIPSO measurements, we now have unprecedented information about TTL cloud frequencies, heights, optical depths, thicknesses, etc. We are using these observations, along with the Aura MLS water vapor measurements, to constrain simulations of TTL transport, cirrus formation, convective hydration/dehydration, and water vapor. The simulations are driven by meteorological analysis temperature and wind fields, with adjustments to correct for temperature biases. Convective injection events are specified

based on geostationary infrared cloud imagery. We anticipate that the comparisons between the measured and simulated cloud properties and water vapor concentrations will shed light on issues such as the threshold supersaturation required to nucleate ice crystals, the importance of gravity waves affecting cloud properties, the impact of different assumptions about TTL vertical ascent rates, and the hypothesis that convective injection could decouple the stratospheric humidity from the tropopause temperature.

65. A study of pollution impacts on upper-tropospheric ice clouds with MLS, CloudSat and CALIPSO data

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Asian anthropogenic aerosol production has been increasing steadily in the past three decades. Can this rise create significant effects on properties of upper-tropospheric \(UT\) ice clouds and consequently on climate change? Is there any Twomey effect on UT ice clouds? Motivated by these questions, we studied cloud properties as observed by Aura MLS, CloudSat and CALIPSO during July 2006, and found a significant correlation between UT carbon monoxide (CO) and ice clouds of small ice particles at 13-16 km altitudes. The ice particle information is inferred from two analyses. One is from a joint analysis of MLS 240 and 640 GHz radiance measurements at these altitudes, and the other is from a joint analysis of CloudSat radar reflectivity and CALIPSO lidar backscatter. Both analyses yield consistent global maps, showing most of small-particle clouds spread over entire Asia with a peak around the Tibetan Plateau and large-particle clouds primarily peaked over the Philippines and the Bay of Bengal. These observations suggest that in a polluted UT region clouds are likely to form with more smaller ice particles. More analyses are needed in the future study to determine the statistical significance and seasonal variations of this pollution-cloud connection.

66. Influence of lightning-produced NOx on upper tropospheric ozone using TES/O3&CO, OMI/NO2&HCHO in CMAQ modeling study

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Lightning provides an important NOx (LNOx) source to the upper troposphere which can affect ozone concentration (local or remote) significantly. A case study was performed to estimate the LNOx influence on ozone concentration around Texas area during Aug. 24-25, 2000, by apply LNOx (which is calculated from NLDN measured lightning data) as an extra NOx emission to the CMAQ model run. Compared to the control run (without LNOx input), the maximum ozone enhancement was shown and we found a remote source of LNOx by backward trajectory analysis. By cutting off this LNOx source, the ozone enhancement was reduced by 50%. Our future work will focus on the distinctive ozone maximum discovered above the southeastern USA during Aug. 2006. Again we will use CMAQ model to simulate ozone variation and to quantify the possible contribution of LNOx to this ozone enhancement. IONS06 ozone measurements and satellite retrievals (O3, CO, NO2, HCHO) will be used to evaluate CMAQ results.